Alberta Heritage Foundation
for Medical Research

CENTRE FOR
ADVANCEMENT
OF HEALTH

Hyperbaric oxygen treatment in Alberta

Craig Mitton and David Hailey

April 1998

HTA 8

Hyperbaric oxygen treatment in Alberta

Craig Mitton
Centre for Advancement of Health, University of Calgary

David Hailey
Alberta Heritage Foundation for Medical Research

April 1998

This Health Technology Assessment Report has been prepared on the basis of available information of which the Foundation is aware from public literature and expert opinion, and attempts to be current to the date of publication. It has been externally reviewed. Additional information and comments relative to the Report are welcome, and should be sent to:

Director, Health Technology Assessment
Alberta Heritage Foundation for Medical Research
3125 ManuLife Place, 10180 - 101 Street
Edmonton
Alberta T5J 3S4
CANADA

Tel: 403-423-5727, Fax: 403-429-3509

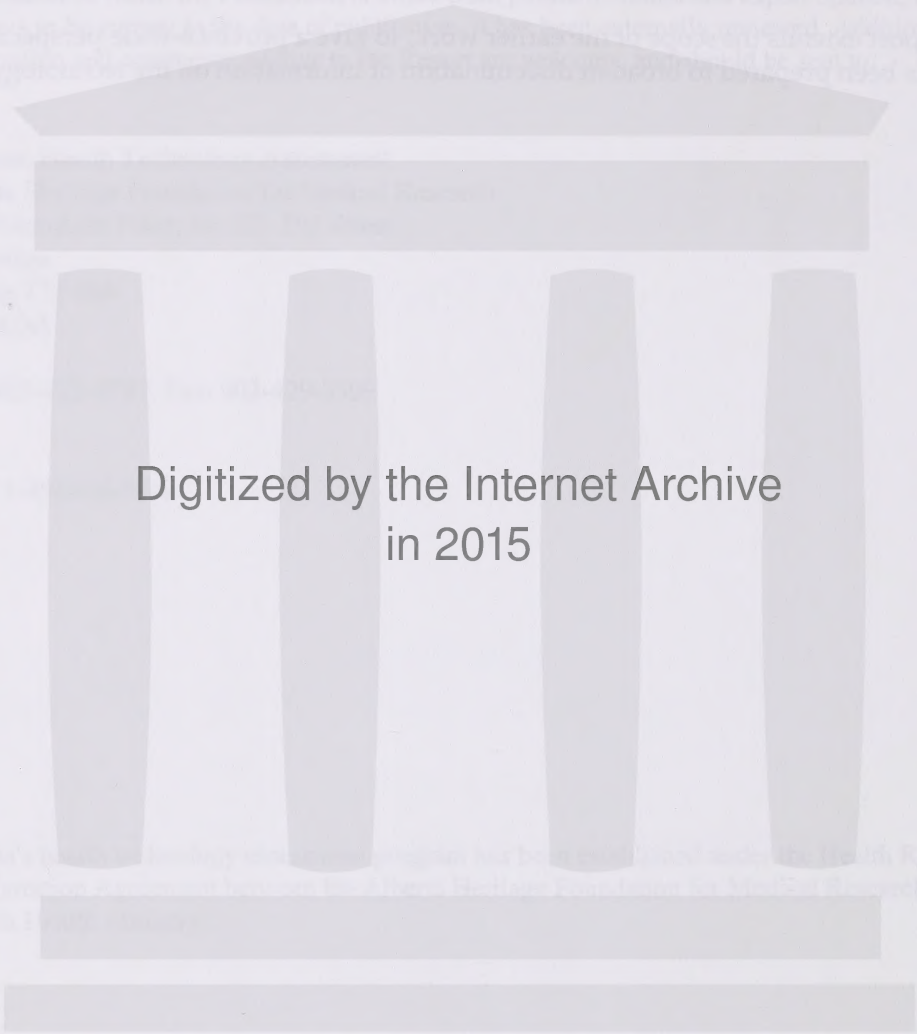
ISBN 1-896956-08-4

Alberta's health technology assessment program has been established under the Health Research Collaboration Agreement between the Alberta Heritage Foundation for Medical Research and the Alberta Health Ministry.

Foreword

This report follows an earlier analysis of requirements for hyperbaric oxygen treatment in the Calgary region, which was undertaken by the Centre for Advancement of Health, University of Calgary, at the request of the Calgary Regional Health Authority.

The report extends the scope of the earlier work, to give a province-wide perspective, and has been prepared to broaden dissemination of information on the technology.



Acknowledgements

The Alberta Heritage Foundation for Medical Research and the Centre for Advancement of Health are most grateful to the following persons for their comments on the draft report and for provision of information. The views expressed in the final report are those of the Foundation and the Centre.

Ms. Marlene Brandt, Calgary Regional Health Authority

Dr. Joseph Dort, Foothills Hospital, Calgary

Dr. Rob Harrop, Foothills Hospital, Calgary

Dr. Eric Kindwall, Medical College of Wisconsin, Milwaukee

Dr. Devidas Menon, Institute for Pharmaco-Economics, Edmonton

Dr. John Nesbitt, Calgary

Ms. Wendy Oczkowski, Calgary Regional Health Authority

Mr. Cliff Seville, Misericordia Hospital, Edmonton

Mr. John Sproule, Alberta Health, Edmonton

Dr. Lloyd Sutherland, Faculty of Medicine, University of Calgary

Mr. Blair Thomson, Calgary Regional Health Authority

Dr. Patrick Tibbles, Memorial Hospital, Worcester, Massachusetts

Ms. Leigh-Ann Topfer, Canadian Coordinating Office for Health Technology Assessment, Ottawa

Dr. Lindell Weaver, Salt Lake City, Utah

Acknowledgements

The Alberta Heritage Foundation for Medical Research and the Centre for Advancement of Health are most grateful to the following persons for their comments on the draft report and for permission of publication. The views expressed in the final report are those of the Foundation and the Centre.

Ms. Marlene Brandt, Calgary Regional Health Authority

Dr. Joseph Doyle, Foothills Hospital, Calgary

Dr. Rob Hornby, Foothills Hospital, Calgary

Dr. Eric Lindwall, Medical College of Wisconsin, Milwaukee

Dr. Deirdre Mowat, Institute for Pharmaco-Economics, Edmonton

Dr. John Nesbitt, Calgary

Ms. Wendy Ozubko-Ash, Calgary Regional Health Authority

Mr. Cliff Serafin, Misericordia Hospital, Edmonton

Mr. John Spronk, Alberta Health, Edmonton

Dr. Lloyd Sutherland, Faculty of Medicine, University of Calgary

Mr. Blair Thomson, Calgary Regional Health Authority

Dr. Patrick Tibbles, Memorial Hospital, Worcester, Massachusetts

Mrs. Leigh-Ann Topfer, Consultant, Continuing Education for Health Technology Assessment, Ottawa

Dr. Lindell Weaver, Salt Lake City, Utah

Contents

Appendices

Tables

Summary

- This report considers current evidence of effectiveness for hyperbaric oxygen treatment (HBOT) and the potential impact on health care costs of a second HBO facility in the province.

- Good evidence of effectiveness exists for HBOT of severe carbon monoxide (CO) poisoning; osteoradionecrosis - mandible; diabetic leg ulcers; and gas gangrene. In addition, HBOT is established as the standard of care for decompression sickness and air or gas embolism

- Some reports suggest a possible use of HBOT for soft tissue radiation injuries and necrotizing soft tissue infections, but the evidence available appears insufficient to support its routine use in treatment of these conditions.

- The available evidence does not support the routine use of HBOT for refractory osteomyelitis; thermal burns; compromised skin grafts / flaps; exceptional blood loss anemia; or ischemic traumatic peripheral injuries (e.g. crush injury, compartment syndrome).

- The existing HBO facility in Edmonton treats about 200 patients per year. Patients are accepted from throughout the province.

- An additional 59-87 patients a year with conditions for which there is good evidence of benefit from HBOT would be eligible for such treatment if a second facility were established in Calgary.

- Establishment of a new HBO facility in Calgary would be unlikely to achieve cost savings to health care. Analysis of available information indicates that there would be additional expenditure, estimated at $108,000 per year if the cost of operation was the same as that of the facility in Edmonton.

- There would be significant benefits through improvement in quality of life of 30-60 persons per year who are unable to travel to Edmonton for HBOT. There would still be access difficulties for such patients in Southern Alberta who do not live in or near Calgary and who are reluctant to travel.

- On the basis of the available evidence on costs and benefits to routine health care, there does not seem to be a particularly strong case for establishing a second HBOT centre in Alberta.

- Other perspectives on the technology will depend on the weight given to quality of life issues and to anecdotal evidence of effectiveness.

Introduction

Hyperbaric oxygen treatment (HBOT) is an old technology which has been available in Alberta for many years. At present, there is one hyperbaric oxygen (HBO) facility, at the Misericordia Hospital in Edmonton. This report has been prepared to provide information to health authorities and others on the available evidence on effectiveness of HBOT and the possible economic impact on health care should a second HBO facility be established in the province. Issues addressed in the report include:

- Whether HBOT has been shown to be effective in the management of a number of conditions;
- Whether introduction of an HBO facility in Calgary would result in cost savings to health care;
- Other benefits to routine health care associated with introduction of a second HBO unit; and
- Overall organizational requirements.

Nature of the technology

HBOT involves administering pure oxygen to the patient at greater than atmospheric pressure. During HBOT, large amounts of oxygen are dissolved into the blood, enabling the maintenance of cell function in the absence of hemoglobin. With this treatment, the blood takes on an increased oxygen carrying capacity, which results in physiologic changes when the hyperoxygenated blood is delivered to tissues. These changes produce the benefits of this treatment. The specific cellular and biochemical effects of HBOT differ for the varying conditions treated.

Hyperbaric oxygen can be administered in monoplace (single patient) or multiplace (multiple patient) chambers. As of February 1996, there were 7 monoplace chambers and 23 multiplace chambers in Canada. Three additional monoplace chamber facilities became operational during 1997. The chambers which are sited in hospitals are located in Vancouver; Edmonton; Moose Jaw; Toronto; Hamilton; Ottawa; Tobermory; Montreal; Halifax; and St. John's. The remaining chambers are affiliated with universities, the military, or professional sports teams (10).

Cost considerations

The cost of HBO units in 1993 varied from $75,000-$85,000 US for a monoplace chamber and from $300,000 to $2.5 million US for a multiplace chamber (45). Additional costs for renovations or construction to house the chamber could be substantial. For a multiplace chamber, up to 4,500 square feet could be required (45), although some consider that only 1,000 square feet to be necessary (Tibbles, personal communication). At an average

renovation cost of $100 per square foot (45), these costs could amount to between $100,000 and $450,000 US. There will also be maintenance costs. Advice from the unit in Hamilton (Nesbitt, personal communication) is that set-up costs for the centre were less than $250,000 and that maintenance costs are $5,000/year per monoplace chamber.

Physician fees in Alberta for HBOT are $26.50 per 15 minutes, but cannot be charged beyond the initial session in a multi-session course of treatment. The HBO facility at the Misericordia Hospital, Edmonton has 2 monoplace chambers, operates on 10-16 hour days, and conducts approximately 1,600 dives per year. The current case load is about 200 patients per year. This facility has an annual operating cost of about $160,000 and associated physician fees of about $26,500 (Seville, personal communication).The total current cost for the Edmonton facility is therefore approximately $190,000 per year.

A recent study by a group in Hamilton estimated a cost per dive of $350, which included capital and operational costs, physician fees, and patient costs.(16) For the purposes of this report, a cost per dive of $220 has been assumed (Appendix A).

Staffing costs for larger multiplace HBO facilities in the US are reported to be about $350,000 U.S (Tibbles, personal communication). Staffing costs represent about 50-60% of total operating costs for these larger chambers (45).

Safety considerations

The major absolute contraindication for HBOT is untreated pneumothorax. Several drugs have also been reported as absolute contraindications. Relative contraindications such as upper respiratory infections and chronic sinusitis, obstructive lung disease, seizure disorders, emphysema with CO_2 retention, previous ear surgery or injury, claustrophobia, high fevers, history of spontaneous pneumothorax, history of thoracic surgery, history of surgery for otosclerosis, viral infections, and congenital spherocytosis have been reported (34,54).

Several complications have been reported with HBOT. These include minor or moderate pain in ear or sinuses; claustrophobia; mild barotrauma; infrequent ruptured tympanic membrane; pressure and patient dependent oxygen seizures; transient myopia; and reversible myopia. Other reported side effects include: numb fingers, dental problems, and round window blowout. The reported incidence of these complications is low (34,4,54).

Contrary to case reports of a carcinogenic effect of HBOT, several reviews have found that, HBOT is highly unlikely to produce cancer (24). In general, HBOT is viewed as a safe treatment from which few patients have serious side effects. When measured against the potential benefit from this procedure for some conditions, the risk is outweighed in the majority of patients. A more complete discussion of the contraindications and complications of HBO is given by Kindwall (34).

Approaches to assessment

In this report, the application of HBOT is considered for twelve conditions. For each of these, the current relevant evidence of effectiveness is presented. Where possible, the level of evidence is specified according to the classification given by Sackett (48) (Appendix B). A limitation here is that HBOT has been used in management of some conditions for many years, and is overwhelmingly regarded as the standard of care in these. Well-designed trials for use in these indications are not reported in the literature, and it is improbable that any will be forthcoming.

Following review of the literature, a review of costs for HBOT of each condition is presented. The cost analysis draws on utilization data from Region 4 (Calgary Regional Health Authority). It compares the cost to health care of an additional HBOT facility in Calgary with that of using the existing services in Edmonton. Numbers of patients treated in Region 4 who could have been candidates for HBOT provide some indication of potential unmet demand for the technology.

Finally, general conclusions are presented regarding the potential costs and effectiveness of HBOT, with particular reference to having HBOT available in Calgary. Details of the methodology used for the literature review and the cost analysis are given in Appendix A. Table 1 summarizes various items and their associated costs used in the analysis.

Table 1: Summary of cost items

Item	*Cost*
HBO Monoplace chamber	$75,000-85,000 U.S. (1993)
HBO Multiplace chamber	$300,000-2.5 million U.S. (1993)
Renovation costs to house an HBO facility	$100,000-$450,000 U.S. (1993)
Estimated operating cost of Edmonton's 2 monoplace HBO chambers (including physician fees)	$186,500 per year
Estimated cost per HBO dive including physician fees and capital and operating costs	$220
Physician fee (Alberta) for HBO per 15 minutes	$26.50
Land emergency transport Calgary to Edmonton	($2.08/km*300km)=$800
Air emergency transport Calgary to Edmonton (fixed wing)	($8/air mile*140 air miles) = $1,440

Primary medical indications for HBOT

1. Decompression sickness and arterial gas embolism

Evidence from the literature

Only reviews and level V evidence were found in the literature. Pelaia et al. (43) reported on a case series of 14 patients, with arterial gas embolism, who responded positively to HBOT. A case series was also reported by Kol et al. (37). who found HBO to be an effective treatment in 6 patients with air embolism following cardiac surgery. Several review articles state that HBO is an effective treatment for arterial gas embolism and decompression sickness (20,41,52).

Although no studies with a high level of evidence were identified, theoretical considerations, physiological evidence and widespread use in clinical practice throughout the world indicate HBO is the treatment of choice for this condition. Kindwall (personal communication) has noted the significance of earlier work with HBOT.

In some cases, time to treat can be extremely critical. For those cases in which transport is possible, air transport may have to be used. If HBOT is not conducted for arterial gas embolism, death is likely. Downstream costs due to serious debilitation may be high if HBOT is not received for decompression sickness. No cost data for HBOT in these two conditions were identified in the literature.

Region 4 utilization and cost analysis

Region 4 reported one case of air/gas embolism in the fiscal year 1996/97. No cases of decompression sickness were reported. Based on Foothills Medical Centre (FMC) costing reports, this case had a length of stay (LOS) of 7 days, and a total treatment cost of $10,459. (See Appendix A for derivation of FMC costs).

There are two potential comparators to the scenario of having HBOT in Calgary. In the first, some patients would be transported to Edmonton to receive HBOT. If this were the case, the correct comparison is HBOT in Calgary vs. the current standard practice of HBOT in Edmonton. The projected costs of HBOT in Calgary (with additional costs of hospitalization, etc. factored in) can be compared to those of providing HBOT in Edmonton for patients from Southern Alberta, including transportation and accommodation costs. It is this cost difference which will determine whether availability of HBOT in Calgary would result in cost savings. Assuming the costs of HBOT in Edmonton are equal to the costs for this service in Calgary, the only incremental costs are for transportation and accommodation, if the service is received in Edmonton rather than Calgary.

Most patients in this category respond to one session in the HBO chamber, and so would need to spend only one day in Edmonton for HBOT. Based on the transportation costs calculated in Appendix A, the cost savings of having HBOT available in Calgary, for this condition, would be approximately $1,600 per patient. This is based on $1,440 for the emergency air transport with food costs for one day of $50, with provision for overnight stay in Edmonton.

If the patient is not able to be transported to Edmonton, the appropriate comparison is between HBOT if it were available in Calgary and treating the patient without HBO in Calgary. The available FMC data are for one patient, not treated with HBO, at a cost of $10,459. No Alberta costing data are available for treatment of decompression sickness utilizing HBO. However, a U.S. estimate indicated this figure to be under $500 (Tibbles, personal communication). As such, for those patients who would not be able to travel to Edmonton, and would be eligible for HBOT in Calgary if it were available, an incremental cost savings up to $10,000 per patient might be achieved, as compared to treatment without HBO.

Very few patients with these conditions would normally be seen in Calgary. Perhaps two cases per year might be taken as an upper limit. If that assumption is made, expected cost savings of having HBOT available in Calgary, due to this condition, would range from $1,600 to $3,200 if HBOT treatment were provided in Edmonton and from $10,000 to $20,000 if alternative treatment in Calgary is used as the comparator.

Summary

- Strong evidence supporting the effectiveness of HBO in the treatment of this condition is not available, but HBO is accepted as the standard of care in clinical practice.
- Some patients with these conditions are critically ill and are too unstable for any type of transport, or would require emergency air transport to the nearest HBO facility.
- Cost savings per patient with decompression sickness and arterial gas embolism would be between $1,600 and $10,000 per year, if HBOT was available in Calgary.

2. Carbon monoxide poisoning

Evidence from the literature

Table 2: Reports on HBO for the treatment of carbon monoxide poisoning

Trial	*No. of Patients*	*Control to HBO*	*Evidence Level*	*Results*
Weaver et al. (53) (1995)	50 (25 in each arm)	100% O_2 at 1.0 atm in hyperbaric chamber	Level I (blinded)	Non-significant difference between HBO and control group on persistent and delayed neuropsychological sequelae (DNS)†
Raphael et al. (46) (1989)	343 (170 NBO and 173 HBO)	100% normobaric O_2	Level II (not blinded)	Non-significant difference in neurological deficits††
Thom et al. (51) (1995)	60 (30 in each arm)	100% normobaric O_2	Level II (not blinded)	Significant decrease ($p<.05$) in incidence of DNS at discharge and 4 weeks in HBO gp†††
Ducasse et al. (19) (1995)	26 (13 in each arm)	100% normobaric O_2	Level II (not blinded, small n)	Significant decrease ($p<.05$) in morbidity (DNS) in HBO group
Gorman et al. (25) (1992)	100 (24% loss to followup) (8 NBO, 24 single HBO, 68 multiple HBO)	100% normobaric O_2 and one HBO session vs. two or more HBO sessions	Level III (longitudinal study of consecutive patients - contemporary controls)	Significant decrease ($p<.005$) in morbidity (DNS) in HBO group at discharge and 1 month; significant increase ($p<.05$) in morbidity if HBO was delayed

† As of Aug. 18, 1997, 123 patients had been enrolled in this study. Interim analysis is being carried out at every 50 patients. After 100 patients, a non-significant difference on neuropsychological sequelae still existed between O_2 and HBO groups (L. Weaver, personal communication); study as cited in table is in abstract form, and has not yet been published in full.

†† Study has been subjected to criticism as the authors did not include patients with severe CO poisoning.

††† Study has been subjected to criticism as the authors did not include patients with severe CO poisoning and the patients and examiners were not blinded to the treatments given.

The literature reviewed does not clearly indicate that reductions in delayed neuropsychological sequelae (DNS) may result with HBOT for carbon monoxide poisoning. Two studies with good levels of evidence found no significant difference between the control (normobaric oxygen) and treatment (HBO) groups with respect to DNS (45,52). Further, no evidence was found which reported shorter hospitalization stays and decreased mortality rates. HBOT is regarded by the Underwater and Hyperbaric Medical Society (UHMS) as a treatment of choice. However, on the basis of the available literature, further evidence is required to establish HBOT as the best treatment for patients with this condition.

A previous review concluded that HBOT should be used only in more severe CO poisoning cases (52). Importantly, time to treatment is a factor: time from event to HBOT should not exceed 2-6 hours. Treatment with HBO for smoke inhalation and cyanide poisoning is not recommended unless patients are presenting jointly with CO poisoning. No costs were identified in the literature, although it could be assumed that

indirect (non health care system) costs would be high due to some patients with severe sequelae being prevented from returning to work immediately.

Region 4 utilization and cost analysis

Region 4 reports 35 inpatients were treated for CO poisoning for the fiscal year 1996/97, and an additional 116 patients presented to emergency from July 1996 to March 1997. Of these patients, 22 were treated at FMC, with an average LOS of 10 days, and an average cost per case of $4,362.

Although a large number of CO poisoning cases presented in Region 4 during 1996/97, not all such cases would necessarily require HBOT. Those patients that are deemed to require HBOT, probably those who are more severely poisoned, can be sent to Edmonton. It is difficult to estimate the number of more severe cases per year, as no widely used grading scheme for the severity of this condition exists. However, based on data from the Edmonton HBO facility, it is unlikely that more than 20 patients per year from Southern Alberta would be expected to receive HBOT in Edmonton. If HBOT was available in Calgary, it is likely that more patients would receive this therapy, but this would be at a large economic cost and without good evidence of effectiveness.

Most patients with CO poisoning who receive HBOT respond quickly and generally need only one day of treatment. Land transport costs, accommodation for one night and food are $950 per case. For an annual caseload of 20 patients, total cost savings of having this treatment available in Calgary for this condition are about $19,000 per year. Air transport may be indicated for some patients, which would increase the cost savings through having HBOT in Calgary. It is difficult to estimate the number of patients who would require air transport. If 50% of the patients required air transport, at $1,440 plus $150 in accommodation and food, the cost for these 10 cases would be $15,900. The cost for the other 10 patients would be about $9,500 (10*$950) so that the total cost savings of having HBOT available in Calgary could be as high as $25,400.

Summary

- The literature provides disparate views on the effectiveness of treating CO poisoning with HBO. The study with the highest level of evidence does not indicate that the majority of CO poisoning cases should be treated with HBO.
- Other reviews have suggested that HBOT can be recommended for more severe CO poisoning cases.
- The estimated cost savings of having HBOT available in Calgary, for this condition, are between $19,000 and $25,400 per year, depending on assumptions made about the need for air transport.

3. Gas gangrene

Evidence from the literature

Table 3: Reports on HBO for the treatment of gas gangrene

Trial	*No. of Patients*	*Control to HBO*	*Evidence Level*	*Results*
Bakker (2) (1988)	409 total	Historical controls which were treated without HBO	Level IV	Roughly <20% mortality in patients with HBO vs. a mean of 50% mortality when HBO not included; also gives lit review suggesting benefits of HBO
Hart et al. (31) (1990)	none	-	Review	States substantial decrease in morbidity and mortality when HBO is included in treatment regime; 6-8 sessions; worse outcome if HBO delayed
Hirn et al. (32) (1993)	32	-	Level V & Review	Found 28% mortality with HBOT; past studies have shown about 50% mortality when HBO not included in treatment; average 5.5 sessions; extensive review indicating HBOT support but no RCTs

No level I-II evidence exists, which has led some authors to criticize the evidence suggesting that HBOT is effective. However, there is a strong rationale for its use, and most studies (lower levels of evidence) reported in the review articles suggest positive results. The evidence suggests significant reductions in both mortality and morbidity when treatment includes HBOT, as compared to surgery and antibiotic treatment. In addition, the literature indicates that mortality and morbidity are further reduced when HBOT is initiated rapidly. As these patients are seriously ill, lengthy hospitalizations can be expected, although no literature reviewed included specific length of stay estimates. No cost data were identified in the literature.

Region 4 Utilization and cost analysis

Region 4 reports 4 inpatients in 1996/97, and one additional patient who presented in emergency between July 1996 and March 1997. Two patients with gas gangrene were treated at FMC. The average LOS for these patients was 32 days, and the average cost per case was $19,418. This figure would rise if potential amputation and rehabilitation costs were included.

HBO session costs, if a facility were available in Calgary, would amount to about $2,860 per case (assuming 13 sessions*$220/session), but there would be additional surgical, antibiotic and miscellaneous costs. When all factors are considered, the cost savings resulting from receiving HBOT vs. not receiving HBO in the treatment regime would be minimal. This is the appropriate cost comparison for those patients who are too

unstable to be transferred to another location to receive HBOT. Most patients with this condition could be expected to be too unstable to transport to Edmonton for treatment.

There is some evidence that amputation rates decrease with use of HBOT, but no study has provided substantive evidence that this is so. Further, it has been reported that up to 10% of patients still have amputations after receiving HBOT for gas gangrene. The significant costs from those patients for whom HBOT (in conjunction with surgery and antibiotics) was not successful would decrease the actual cost savings when comparing the HBOT and non-HBOT options.

The literature indicates that time to treatment with HBO is critical to the reduction in mortality and morbidity resulting from gas gangrene.

Summary

- Although no level I evidence exists, significant reductions in mortality and morbidity have been reported when HBOT has been added to surgery and antibiotics in the treatment of gas gangrene.
- In comparing treatment regimes with and without HBO the costs are likely to be similar due to the high costs of HBO therapy.

4. Radiation tissue damage: Osteoradionecrosis (ORN) or soft tissue damage

Evidence from the Literature

Table 4: Reports on HBO for the treatment of osteroradionecrosis

Trial	No. of Patients	Control to HBO	Evidence Level	Results
Dempsey et al. (15) (1997)	42 (21 in each group)	Hypothetical non-HBO group	Level IV	HBO group more effective and HBO was a cost saving treatment
Marx (38) (1983)	58	none	Level V	All 58 patients had complete resolution of ORN with HBO as an adjunct; 90-135 hours of HBO required
McKenzie et al. (38) (1993)	26	none	Level V	21/26 patients improved following HBO as part of treatment regime for ORN
Sheps (48) (1992) (BCOHTA)	-	-	Review	HBO may be a useful adjunct for ORN; further research required
Marx et al. (39) (1985) (treatment of radiation caries)	74 (37 in each arm)	Penicillin	Level II (not blinded)	ORN resulted in 5% of HBO group vs. 30% of antibiotic group ($p<.005$)

ORN is a seriously debilitating disease which requires extensive treatment at considerable cost. HBOT has been shown to be a valuable adjunct in the treatment of ORN when used with surgery (and possibly other treatments as warranted on a case by case basis). The treatment protocol for ORN involving HBOT can require over 100 hours in the chamber. The literature does not state that time is a critical factor for receiving HBOT. Although results are promising, further studies are needed to provide a clearer picture of the effectiveness of HBOT for this condition.

A 1997 study by Dempsey et al. in Hamilton (16) compared a case-matched hypothetical non-HBO group to an actual group of 21 patients who received HBOT for ORN. It was estimated that the HBO-group had significantly better outcomes and incurred fewer costs.

The major problem with this study is that estimates of non-HBO outcomes were based on only a few previously-conducted studies. As well, no citation was provided for the estimate of non-HBO length of stay, which proved to be the only factor which caused a wide variation of results in the sensitivity analysis. In the present assessment, no study was identified which reported LOS to be significantly reduced in an HBO compared with a non-HBO group. The report of the Hamilton study did not include length of stay data for the HBOT patients. Therefore, there is some uncertainty as to the validity of the cost savings identified. The study by Marx et al. on the treatment of radiation caries to prevent ORN has also been included in Table 4.

Treatment of soft tissue radiation injury with HBO has also been discussed in the literature. However, only case reports were identified. These low level evidence reports have, in general, suggested that HBOT be used as an adjunct to surgery and other means of treatment. Better quality evidence of benefit for treatment of soft tissue radiation injury would be desirable but may be unlikely. Kindwall (personal communication) has noted that clinicians see previously non-healing wounds which have been open for months or years go on to heal within a matter of a few weeks. No cost data were identified in the literature.

Region 4 utilization and cost analysis

Region 4 reports 12 patients were treated with ORN - mandible for the 1996/97 fiscal year. No cost information or LOS data were available for this report. A local estimate is that the number of patients eligible for HBOT each year would be about two thirds of the 20 - 30 major head and neck resections performed each year (Dort, personal communication).

Despite HBOT being an important and valuable adjunct for the management of ORN - mandible, most Calgary patients with this condition do not receive this treatment. These persons are generally elderly patients for whom a trip to Edmonton is not feasible. These individuals have a decreased quality of life because they cannot eat solid foods (Dort, personal communication).

As these patients do not usually receive treatment in Edmonton, the appropriate cost comparison is treatment including HBO with a regime not including HBO. As discussed above, one study found HBO costs to be less than non-HBO costs. However, if the key variable in the non-HBO costs is changed cost savings are reduced substantially. A prospective study analyzing the costs of HBO vs. non-HBO for the treatment of ORN needs to be undertaken.

No Region 4 cost data are available in comparing treatment including HBO vs. a regime which does not include HBO. It is not known if substantial cost savings would result. However, the key point in this discussion is that those patients who do not receive HBOT in Edmonton will have decreased quality of life.

Summary

- It is not known if cost savings would result for treatment of ORN if HBOT was available in Calgary.
- Most patients with this condition will have a decreased quality of life as they will not travel to Edmonton to receive HBOT.

Adjunctive medical indications for HBOT

1. Necrotizing soft tissue infections (necrotizing fasciitis, Fournier's disease)

Evidence from the literature

Table 5: Reports on HBO for the treatment of necrotizing soft tissue infections

Trial	*No. of Patients*	*Control to HBO*	*Evidence Level*	*Results*
Brown et al. (7) (1994)	54 total	antibiotics and surgery	Level III	42% mortality without HBO vs. 30% with - NS difference; NS decrease in # of debridements; no difference in LOS; RCTs required†
Hollabaugh et al. (33) (1988)	26, 14 treated with HBO	antibiotics and surgery	Level IV	42% mortality without HBO vs 7% with
Riseman et al. (47) (1990)	29 total	antibiotics and surgery	Level III	66% mortality vs. 23% mortality - sig reduction in HBO gp ($p<.02$); sig less debridements - 1.2 vs. 3.3 ($p<.003$)
Gozal et al. (26) (1986)	16	none	Level V	Mortality rate of 12.5% in patients treated with antibiotics, surgery and HBO
Eltorai et al. (21) (1986)	10	none	Level V	9/10 had HBO as an adjunct to surgery and antibiotics and none of the 10 died; 4-40 sessions
Zamboni et al. (52) (1990)	6	none	Level V	6 patients received HBO as an adjunct to surgery and antibiotics - no 30 day mortality, 1 late mortality (pneumonia)

† Authors state that their study had a selection bias in the HBO group which may account for the non-signficant results.

No level I-II evidence of the effectiveness of HBOT as an adjunct for treatment of necrotizing soft tissue infections was found in the literature. Available evidence is based on studies with non-randomized control groups and case reports. There are many forms of such infections, and HBOT has not been found to be effective for all. However, Kindwall (personal communication) advises that necrotising infection involving microaerophilic streptococcus, which causes Fournier's disease, is a common presentation. Mortality has been shown to decrease, and overall outcomes improve when HBOT is used for certain infections. HBOT seems effective for some forms of this illness, but on the basis of the available literature, stronger evidence of benefit would be desirable. No cost data were identified in the literature.

Region 4 utilization and cost analysis

Region 4 reports 124 inpatient cases for the 1996/97 fiscal year, and 15 emergency cases between July 1996 and March 1997. 58 patients were treated at FMC. The average LOS was 29 days, and the average cost per patient was $23,600.

As necrotizing soft tissue infections is a broad term which encompasses many forms of illness, a valid general statement regarding the use and cost effectiveness of HBO as part of the treatment regime may not be possible. There is some evidence which suggests that mortality and morbidity will be reduced with adjunctive HBOT for some forms of this illness, so that there may be some cost savings, and Kindwall (personal communication) has drawn attention to good experience with use of HBOT for Fournier's disease. It is suggested that HBOT should be considered on a case by case basis; until further studies are conducted, there will be some uncertainty on the degree of effectiveness of HBOT for these conditions.

HBOT session costs are about $6,300 per case (30 sessions). There would be additional costs from surgery, antibiotics and other treatments used in conjunction with HBOT. When these additional costs are considered, it is unlikely that substantial cost savings would be realized as the average treatment cost when HBO is not utilized is only $23,600. For cases which require HBOT, transportation and accommodation costs for receiving treatment in Edmonton would approximate the cost savings of having HBOT available in Calgary.

Summary

- HBOT appears useful in the management of Fournier's disease, but better evidence to establish its effectiveness in management of soft tissue infections would be desirable.

- Significant cost savings for treatment of this condition are unlikely to be achieved through making HBOT available in Calgary.

2. Wound healing in selected patients

Evidence from the literature

Table 6: Reports on HBO for the treatment of lower wound extremities

Trial	*No. of Patients*	*Control to HBO*	*Evidence Level*	*Results*
Faglia et al. (23) (1996)	68 (35 in HBO group, 33 in non-HBO group)	surgery and antibiotics without HBO	Level I (blinded)	Significant lower amputation rate when HBO included in regime - 8.6% vs. 33.3% (p=.016); mean sessions 39
Hammarlund et al. (28) (1994)	16 total	Air at 2.5 atmospheres	Level II (blinded, small n)	NS reduction in wound area at 2 weeks for chronic leg ulcers; sig reduction at 4 (p<.05) and 6 wks (p<.001) in HBO group; 30 sessions
Doctor et al. (17) (1992)	30 total	surgery and antibiotics not including HBO	Level II (not blinded, small n)	7% amputation in HBO group vs. 23% in group without HBO (p<.05); no difference in LOS reported
Baroni et al. (3) (1987)	28 (18 in HBO group, 10 in non-HBO group)	surgery and antibiotics not including HBO	Level III (non randomized control gp)	89% healed in HBO group (amputation in 11%) vs. control group of 50% unchanged, 40% amputation, 10% improvement (p=.001); 62 days LOS average in HBO group vs. 82 days LOS in control
Cianci et al. (11) (1993)	-	-	Level V	Reports on series of 41 patients - salvage rate of 78%; HBO charges of $15,900; total hospital charges of $32,000; avg LOS 27 days; compare to primary amputation + rehab costs of about $80,000

There is strong evidence to support the use of HBO for the treatment of diabetic leg and foot ulcers and some evidence to support the use of HBOT for chronic leg ulcers. Patients who have received HBOT have consistently been shown to have better healing rates and fewer amputations than non-HBOT patients. Although there is some evidence indicating a decrease in length of hospital stay, the literature in general does not indicate substantial nor significant reductions.

Kindwall (personal communication) advises that use of transcutaneous pO_2 measurements allows prediction of which patients will heal if HBOT is used. Patients with low pO_2 values in areas surrounding the ulcer are potential candidates for HBOT, but are not treatable if the pO_2 does not rise above specified values when they are tested while breathing oxygen at a pressure of 2.5 atmospheres. For those eligible for such a protocol, treatment should be discontinued if the pO_2 does not rise within the first 14 days of HBOT.

Region 4 Utilization and Cost Analysis

Region 4 reports 141 inpatient diabetic leg and foot ulcer cases for the fiscal year of 1996/97, and an additional 33 emergency cases from July 1996-March 1997. Of these patients, 75 were treated at FMC, with an average LOS of 18 days, and an average cost per case of $9,702. Amputation and rehabilitation costs would increase this figure substantially.

It is estimated that 67% of lower extremity wound patients respond to conventional treatment.(24) Further, not all of the non-responders to conventional treatment would be eligible for HBOT, on the basis of pO_2 criteria. It is estimated that 20-40 patients per year with lower wound extremity patients from Calgary would benefit from HBOT.

The cost saving per patient from having HBOT available in Calgary is difficult to calculate. Costs of primary amputation plus rehabilitation might be $120,000 per patient. Further ipsilateral and contralateral amputations would increase these costs. The literature indicates that about 30% of patients treated conventionally without HBOT require amputation. About 8% of patients whose treatment included HBO also require amputation. Conventional treatment without HBOT, based on FMC data, costs about $9,700 per case. Costs of HBOT for this condition have been estimated at about $15,000 U.S., with total hospital charges for patients who received HBOT of about $31,000 U.S. per case (12).

A 1995 study by Apelqvist et al. (1) retrospectively described long term (to 3 years) costs of 274 patients who were treated for diabetic foot ulcers. Costs for those patients with critical ischemia who healed was $26,700 U.S., and for those without critical ischemia was $16,100 U.S. Costs for patients who healed after a minor amputation were $43,100 U.S. and $63,100 U.S. for those who had a major amputation.

Without a prospective study with HBO and non-HBO groups from the same population, it is impossible to determine if cost savings would result with the HBO regime. Though the number of amputations that may be avoided can be determined from previously-reported data and expected cost savings calculated, such an approach would not consider all of the costs which are incurred in complex therapeutic pathways, and could be misleading.

As with ORN patients, the majority of patients with diabetic leg ulcers are elderly, and in general do not want to travel to Edmonton to receive HBOT. Consequently, some patients must endure a decreased quality of life as HBOT is not available currently in Calgary.

A further consideration is that availability of HBOT might lead to home care program cost savings, as there could be an increase in wound healing and a consequent decrease in use of home care. Potential cost savings cannot be calculated from available data. There would be a need to obtain home care visitation costs and data indicating how

many of these patients are likely to have sufficient healing with HBOT to make further home care visiting unnecessary. Finally, the downstream costs with amputation, including lost wages and home care costs, could be considerable, thus increasing the cost savings found with HBOT.

Summary

- HBOT for the treatment of diabetic leg ulcers has been found to be a valuable addition to the treatment regime.
- Approximately 20-40 patients per year from Region 4 who have this condition are eligible for HBOT.
- The potential cost savings in having HBOT available in Calgary are not known.
- Patients treated without HBO in Calgary will have a decreased quality of life, due to the higher amputation rate that will result.

3. Skin grafts and flaps (compromised)

Evidence from the Literature

Table 7: Reports on HBO for the treatment of compromised skin grafts and flaps

Trial	*No. of Patients*	*Control to HBO*	*Evidence Level*	*Results*
Perrins (44) (1967)	48 (24 in each group)	surgery and wound care not including HBO	Level II (not blinded)	Significant increase in graft survival with HBO ($p<.01$)
Bowersox et al. (8) (1986)	105	-	Level V (case series)	Survival rate with HBO of 90%
Kindwall et al. (36) (1991)	-	-	Review (level III-V included)	Increase in survival of grafts when HBO included in regime; range of 6-20 sessions and $1500-$5000

A sound RCT (level II evidence) from 1967 supports HBOT for this condition. However, no further level I or II evidence was found in the literature. The majority of studies identified were in animals. Additional good quality studies in humans are needed. Opinion at FMC suggests that although some people in the field are enthusiastic about using HBOT, others are cautious about its potential and consider that the evidence for HBO effectiveness in this field is not clear (Harrop, personal communication).

This is a complex issue. The evidence does not clearly suggest a course of action with respect to use or non use of HBOT.

Region 4 Utilization and Cost Analysis

The available evidence does not clearly support the use of HBO for the treatment of compromised skin grafts and flaps. It is not appropriate to conduct a cost analysis on a treatment which has not been shown to be medically effective.

Summary

- There is not sufficient evidence to recommend that patients with this condition undergo HBOT as part of the treatment regime.

4. Chronic refractory osteomyelitis

Evidence from the Literature

Esterhai et al. conducted a case matched study of 28 patients, comparing surgery and antibiotics in conjunction with HBO to a regime which did not include HBO, on healing rates (level III evidence).(22) No difference in healing rates between the two groups was found. However, Kindwall (personal communication) notes that this study has been criticised for having controls who did not in fact have refractory disease. Several review articles were identified in the literature, but each presented limited evidence supporting the effectiveness of HBOT (9,35,49).

Kindwall (personal communication) suggests that the role of HBOT is significant in certain cases, though only about 11% with this condition need HBO. A study by Davis et al. (15) found that 34 of 38 patients with this condition remained free of clinical signs of osteomyelitis for an average of 34 months after HBOT. On average, 48 once-a-day treatments are used. Only four of these patients had been free of clinical signs for as long as three months in the two years preceding HBOT.

Available information suggests that HBOT may be helpful for some patients. However, studies with higher levels of evidence are required before conclusions about the effectiveness of HBOT can be made for this condition. With this serious illness, many clinicians feel that if the patient is unresponsive to standard therapy, and as the potential for harm with HBOT is low, that there is no reason why HBOT should not be included in patient management. This attitude, which seems pervasive in the literature, is one which will cause treatments to be utilized when they may not be warranted.

Region 4 Utilization and Cost Analysis

Region 4 reports 57 inpatients were treated in the fiscal year 1996/97 for chronic osteomyelitis, and an additional 4 patients presented at emergency for this condition from July 1996 to March 1997. Only about 10% of these cases are refractory. Only refractory osteomyelitis has shown any indication of responsiveness to HBOT. Thus, even if HBOT was shown to be effective, the numbers of cases which would be eligible

for HBOT would be relatively low (about 6 patients per year). With few patients with this medical condition requiring HBOT, it would be unlikely to produce large cost savings overall. If these patients were to receive HBO, the best option would probably be to receive treatment in Edmonton.

Summary

- Randomized controlled trials for HBOT in this application need to be conducted.
- Until better medical evidence is provided for the use of HBOT for this condition, cost savings cannot be identified.

5. Acute thermal burns

Evidence from the Literature

Table 8: Reports on HBO for the treatment of acute thermal burns

Trial	*No. of Patients*	*Control to HBO*	*Evidence Level*	*Results*
Brannen et al. (6) (1997)	125 (63 in HBO group, 62 in non-HBO group)	Therapy not including HBO	Level I	No stat sig difference between the groups for mortality, # of operations, and LOS
Hart et al. (30) (1974)	16 total	Therapy not including HBO	Level II (blinded, small n)	Sig reduction in healing time in HBO group ($p<.005$); decreases in mortality and morbidity in HBO group
Niu et al. (42) (1987)	266 in HBO group and 609 in control group	Therapy not including HBO	Level III	Significant reduction in mortality in HBO group; but only in the most severely burned. Average LOS not statistically significant
Cianci et al. (14) (1990)	21 (10 in HBO group, 11 in non-HBO group)	Therapy not including HBO	Level III	Sig LOS reduction in HBO group ($p<.043$); lower but not sig lower costs in HBO group
Cianci et al. (13) (1994)	-	-	Review	HBO can be a useful adjunct; further studies required

Overall, numerous studies have shown HBOT to be an important adjunct in the treatment of acute burns. However, the recent RCT reported by Brannen et al. was unable to demonstrate any significant benefit to patients from use of HBO. The generalizability of this study is not clear as non-routine management of the wounds was conducted (Tibbles, personal communication). Many authors state the need for more RCTs with larger numbers for the evidence of HBOT effectiveness can be regarded as conclusive. A leader in the field, P. Cianci, stated in 1994 that further investigation in the field is required (13). Other than the study by Brannen et al., no high level of evidence studies were identified in the literature. A further point is that HBOT for this application could only be considered in a unit which is part of a major burns centre (Kindwall, personal communication).

Region 4 Utilization and Cost Analysis

Region 4 reports over 500 inpatient and emergency visits for burns[1] in the 1996/97 fiscal year. Fifty of these were cases at the FMC, which reports an average LOS of 23 days / case, and an average cost per case of $17,768.

As the evidence in the literature is contradictory as to the medical benefit of HBOT for thermal burns, conclusions on its cost effectiveness for this condition cannot be drawn. Even if HBOT was shown to be effective, it is unlikely that significant cost savings would result, due to the high HBO session costs.

Summary

- The evidence on the effectiveness of HBOT to reduce morbidity, surgical procedures and costs in acute burn patients is contradictory.

6. Acute traumatic peripheral ischemias (crush injury, compartment syndrome)

Evidence from the Literature

The majority of evidence located was level V or animal studies. However, one recent level I study by Bouachour et al. (5) found significant increases in complete wound healing and reduction in repetitive surgery (including amputation) in the HBOT group as compared to not including HBO in the treatment regime. A non-significant difference between the two groups was observed for LOS, number of wound dressings, and healing time. This study included 36 patients and focused on older people with severe crush injuries.

In 1994, Strauss conducted a review of HBOT for ATPIs (50). He presented many case studies which reported decreased morbidity with HBOT, but stated there is limited clinical experience of HBOT use for these conditions.

HBOT for the treatment of ATPIs appears promising for a specific patient group. Further good quality studies are required to establish its role in the management of such conditions. A cost analysis is not warranted until HBO therapy has been shown to be clearly effective.

---

[1]Burns here refers to blisters (2nd degree) and full-thickness skin loss (3rd degree) to genitalia, hand, wrist, foot, ankle, toe and/or 20-49% TBSA. This description was chosen based on the type of burns most often described in the literature as treatable with HBO.

7. Anemia due to exceptional blood loss

Evidence from the Literature

This condition occurs when, for medical, cultural or religious reasons, a blood transfusion is not possible. HBOT has been suggested in these circumstances to provide support until the red cell mass is replaced. The evidence for the use of HBOT for this condition is poor. In the case series reported by Hart, of the 26 patients treated with HBO, 70% survived (29). Despite theoretical indications, there is limited clinical experience in treating such patients with HBO. More research needs to be conducted in this area before it can be concluded that HBO is a medically effective treatment for this condition. No cost calculations are warranted due to the lack of medical evidence.

Overall assessment of HBOT effectiveness

Table 9 summarizes the evidence for effectiveness of HBOT for the conditions considered in this report. The findings of four recent review articles are summarized in Appendix C.

Table 9: Evidence of effectiveness of HBOT

There is strong evidence to support the use of HBOT for the following conditions: Osteoradionecrosis - mandible Diabetic leg ulcers
Evidence supports the use of HBOT for the following conditions: Decompression sickness & air or gas embolism Gas gangrene (clostridial) Severe CO poisoning
There is evidence which suggests a possible role for HBOT but does not establish its usefulness for: Soft tissue radiation injuries Necrotizing soft tissue infections
Available evidence does not support the use of HBOT for: Refractory osteomyelitis Thermal burns Compromised skin grafts / flaps Exceptional blood loss anemia ATPIs (crush injury)

The literature strongly supports the use HBO for the treatment of two conditions.

Osteoradionecrosis has been shown to respond positively to HBOT. Some 13 - 20 patients can be expected to present in the Calgary Region with this condition each year. Many of these patients are elderly and do not want to travel to Edmonton to receive adjunctive HBOT. If these patients refuse HBOT, their quality of life drops dramatically as they cannot eat solid foods. It is not known if a cost savings would result if HBOT was available in Calgary, although it would likely be minimal.

Diabetic leg ulcers have been shown to respond positively to HBOT, with significant decreases in risks of amputation and decreased healing times. An estimated 20-40 patients from Calgary are eligible for HBOT. Most do not receive HBOT because they elect not to travel to Edmonton. These patients are treated alternatively in Calgary with the potential for a worse quality of life outcome. The total cost savings of HBOT for this condition, if HBOT was available in Calgary, is not clear but is suspected to be low.

For some patients with these conditions, access to HBOT would remain uncertain even if a unit was established in Calgary, as they live at some distance from the city.

Sufficient evidence for the medical effectiveness of HBOT was found in an additional three conditions.

Although high level evidence is not given in the literature, HBOT is recognized as the standard of care for **decompression sickness and arterial gas embolism**. The cost savings of having HBOT in Calgary for these conditions could be in the range of $1,600 - $20,000 per year.

The evidence for the treatment of **carbon monoxide poisoning** with HBO is varied. As severe cases are currently treated in Edmonton with HBO, cost savings of HBOT in Calgary would arise through elimination of the incremental cost of transportation and accommodation. Although a large number of patients present with CO poisoning in Region 4 each year, only about 20 are eligible to be sent to Edmonton to receive HBOT. Total estimated cost savings for this condition, if HBOT was available in Calgary, are $19,000 - $25,400 per year.

The evidence of benefit for HBOT for **gas gangrene** is varied. Five patients presented in Region 4 with this condition in 1996/97. It is unlikely that most patients with this condition would be stable enough to be transported to Edmonton. In some cases, helicopter transport might be used. Because of the high cost of HBOT, it is unlikely that availability of the technology in Calgary would result in cost savings over alternative treatments.

The indications of effectiveness of HBOT for these six conditions and identified cost savings associated with its use should a unit become available in Calgary are summarized in Table 10.

Table 10: Summary of HBOT effectiveness and cost savings for six conditions

Condition	*Evidence of effectiveness*	*Region #4 estimated cases per year*	*Estimated cost savings if HBOT was available in Calgary (per year)*	*Additional considerations if HBOT was not available in Calgary*
Osteoradionecrosis	HBO an effective component in the treatment regime	13 - 20	unknown/ minimal	Quality of life for some elderly patients will suffer
Diabetic leg ulcers	HBO an effective component in the treatment regime	20-40	unknown/ minimal	Quality of life for some elderly patients will suffer
Decompression sickness and arterial gas embolism	Poor formal evidence overall but accepted as standard of care	1-2	$1,600 - $20,000	-
CO poisoning	Highest level of evidence suggests HBOT not effective - use only for more severe patients	20	$19,000 - $25,400	Time to treat with HBO should be <6 hours
Gas gangrene	Evidence is varied - mortality and morbidity may be reduced	5	minimal	Time to treat with HBO is critical
Overall summary	***Evidence supports effectiveness of HBO in only these 6 conditions***	*59 - 87*	$20,600 -$45,400	***Some patients with a dramatic quality of life decrease***

The evidence suggests HBOT **may be effective** for necrotizing soft tissue infections and soft tissue radiation injury, but further research is required. Potential cost savings of HBOT for these conditions cannot be included in estimates of overall savings, due to a lack of sound evidence. However, it is possible that future cost savings will arise.

The medical evidence **does not support** the use of HBOT for the following conditions: Refractory osteomyelitis; Thermal burns; Compromised skin grafts / flaps; Exceptional blood loss anemia; and ATPIs (crush injury). Sound conclusions about the effectiveness of HBOT for these conditions cannot be drawn from available evidence.

Other proposed indications for HBOT

Numerous additional medical conditions for which HBOT has been used have been reported in the literature, although none of these are found on the UHMS recommended list. These include: acute myocardial ischemia; deep fungal infections; Crohn's disease; radiation cystitis; MS; spinal cord injury; glaucoma; HIV - fatigue; optic neuropathy; intracerebral hemorrhage; various cancers; rheumatic diseases; headaches; and tinnitus.

Generally, only case series or studies comparing treatment to historical controls have been conducted for HBOT of these conditions. Its use in these applications cannot be supported, on the basis of available evidence. There is a clear need for good quality studies.

Further issues relating to HBOT

Impact of HBOT on bed utilization

For each of the six conditions for which HBOT has clearly been shown to be effective, morbidity rates have been shown to drop when the technology has been used. It might be assumed that bed utilization would also decrease when morbidity rates drop. However, the literature reviewed does not provide evidence on this issue. There is no direct evidence to support this proposition.

Acute vs. home care costs

As with bed utilization patterns, no evidence is provided in the literature regarding acute vs. home care costs. With lower morbidity rates, one may speculate that length of stays and bed utilization would decrease, even though no study was identified which studied these changes. Also, if patients left hospital more quickly, and many were seriously ill when they were admitted, home care costs might actually increase with HBO use. No study which addressed this issue was identified.

General cost, effectiveness and organizational considerations

The cost savings through availability of a second HBO unit in Calgary that have been identified amount to a maximum of about $45,000 per year. These savings would be associated with treatment of up to 87 individuals who would otherwise have been transferred to Edmonton or treated in Calgary with protocols that do not include HBOT.

The costs of establishing an HBO facility in Calgary are uncertain and would depend, among other things, on the type of equipment selected. If a similar facility to that at Edmonton were established, with two monoplace chambers, capital costs might be of the order of $500,000.

Annual cost of the facility would depend on the level of use. The following scenario gives an illustration of possible overall costs for a new facility. At present, the Edmonton HBO unit has about 200 patients per year. Information from the unit indicates that in the 1996-97 fiscal year, 36 of 120 patients (30%) came from Southern Alberta. This could be taken to suggest that, if a unit in Calgary became available, caseload for each unit might be in the order of 140 per year. Such a figure for a Calgary facility is broadly consistent with the total of those patients currently referred to

Edmonton from the south of the province and the estimates of unmet need from the Region 4 utilization data (Table 10).

If the cost per dive was $220, and there was an average of 8 dives per patient, then with a caseload of 140 per year the annual operating cost of the new facility would be about $246,000. Of this total, about $153,000 would be associated with treatment of the up to 87 cases identified in Table 10. Savings identified for these cases are about $45,000. Therefore, there would be an incremental minimum cost to health care of $108,000 per year ($153,000 - 45,000) for treating these individuals at the new facility. This analysis suggests that additional HBO unit in Calgary would not save health care costs.

There would be benefits from an additional HBO unit through improvements to the quality of life of 33 - 60 patients per year who are unable or unwilling to travel to Edmonton for treatment (Table 10). Even with an HBO unit in Calgary, there would still be constraints on such patients, as over 45% of those in southern Alberta live outside Calgary and would face problems with transportation to the facility.

Other projections of costs and benefits could be derived. It could be argued that caseload might increase considerably, and that other savings could be identified. On the other hand, evidence of benefit is weak for many indications and there might be additional incremental costs.

Discussion

In this assessment, the main aims have been to review the evidence of effectiveness of HBOT, and to consider cost implications of a second HBO facility in Alberta. The main sources of information have been studies published in refereed journals and administrative data from within the province.

HBOT has been widely reported as an effective therapy for many medical conditions. It has also been stated that this procedure is a cost effective treatment. On the basis of the evidence available for preparation of this report, a more cautious opinion on this technology seems appropriate. The available evidence provides strong support for use of HBOT in only six conditions: decompression sickness; air or gas embolism; severe CO poisoning; osteoradionecrosis - mandible; diabetic leg ulcers; and gas gangrene.

Despite many proposals for its more widespread use, the literature does not provide reasonable evidence of effectiveness of HBOT for most conditions. Many of the studies in this field are uncontrolled clinical series of 5 to 10 patients. Until higher levels of evidence from good quality studies become available, it does not seem reasonable to support a wider role for HBOT.

Users and operators of HBO units would argue that there is substantial additional evidence that has been accumulated through lengthy clinical experience. Also, some patients may be atypical and be offered HBOT as an intervention of last resort. There

are difficulties in obtaining good quality evidence in such cases. Nevertheless, essentially anecdotal accounts and reports on small, uncontrolled series have limited value if an evidence-based approach is to be taken.

Many authors have suggested HBO to be a highly cost effective treatment. Available information indicates that it is cost-effective in some indications. However, the main economic issue addressed in this report is whether establishing a second HBO unit in the province would be cost-effective. Overall, this report does not support that view, for three reasons. First, high utilization is required to justify the high operating costs of an HBO program. In many cities, the absolute number of patients who are eligible for HBOT is low.

Second, the literature often compares a treatment regime which includes HBO to one which does not. In the case of Alberta, the appropriate comparison is between HBOT in one region and referral for HBOT in another. Estimates of associated cost savings are lower than those reported.

Third, for those conditions which require HBOT to be compared to a protocol without HBOT, all of the costs which are part of the therapeutic pathway need to be taken into account. When all costs are considered, the resultant cost savings through HBOT being available are greatly reduced. When examined across all conditions for which HBOT use has been shown to be clinically appropriate, the technology is less likely to be cost effective.

The estimates presented in this report indicate that introduction of an HBO unit in Calgary would result in an increased cost to health care of about $108,000 per year. While it has not been possible to identify all costs associated with treatment of some conditions, and there is some uncertainty regarding reliability of administrative data, it seems clear that a second HBO unit would not lead to cost savings.

Some patients would have a better quality of life if an HBOT program was available in Calgary. This is a substantial consideration. However, many patients in Southern Alberta are at some distance from Calgary, so that difficulties with transportation to an HBOT facility would remain for some individuals. The extent of overall gains to quality of life is somewhat uncertain.

This assessment has considered the possible impact of a second HBOT facility on routine health care, with a focus on cost effectiveness. Issues such as development of Calgary as a "Centre of Excellence", with involvement in HBO research have not been addressed.

In conclusion, while recognizing the significant disadvantage to some individuals, there does not appear to be a particularly strong case for development of an HBO facility in Calgary, on the basis of identifiable costs and benefits to routine health care. Any additional considerations would depend on the weight given to quality of life issues

and to anecdotal reports. It is suggested that for a province the size of Alberta, one HBO facility is sufficient to meet the indicated demand. Appropriate arrangements should be made to facilitate referral to and transport of all eligible patients to the existing HBO facility in Edmonton.

Appendix A: Methodology and assumptions

Literature review

A search was conducted on the following databases: MEDLINE (1993-1997); HealthSTAR (1995-April 1997); CINAHL (1982-March 1997); and EMBASE (1988-October 1997). The keywords used were "hyperbaric oxygenation" combined with "wound infection". A review of MEDLINE 1966-1997 was also conducted using keywords "hyperbaric oxygen" combined with "effectiveness", "cost*", "economic", and "cost effectiveness".

The intention was to present those studies which had the highest level of evidence, in order to draw reasonable conclusions on medical and economic issues. Only human studies were considered. Studies with low level evidence were excluded for treatment of conditions where higher-level evidence was available. For those conditions where several studies of the same level of evidence were identified, the studies presented are those which had the largest number of subjects.

Cost analysis

Perspective

The perspective taken for the cost analysis is that of the payer, which includes only direct costs.

Assumptions

The following assumptions were made in determining the actual cost savings of having HBOT available in Calgary:

Land emergency transport cost between Calgary and Edmonton is $800. Data from Alberta Health indicate care support for the transport to be about $175, and estimate mileage cost of approximately $2.08/km. With a land distance between the two cities of 300km, the total land transport cost sums to about $800 (J. Sproule, personal communication).

Food costs for one day are assumed to be $50, and overnight accommodation costs are estimated at $100 per night.

Costs of personal travel between Calgary and Edmonton are estimated to be $100 (300km at $0.34/km).

Based on data from Alberta Health, fixed wing air ambulance costs would be approximately $1,440 for a Calgary to Edmonton trip, and helicopter ambulance would be approximately $4,320 (J. Sproule, personal communication). (Estimates are based on

180 air miles between the two cities at a rate of $8.00/mile for fixed wing and $24.00/mile for helicopter.)

For ORN and diabetic leg ulcers, treatment including HBO results in minimal cost savings as compared to non-HBO treatment. This assumption was made as the high session costs of HBOT, coupled with the additional costs of this therapeutic pathway, would likely equal the costs of treatment without HBO.

Generalizability of US data to Alberta

Some of the U.S. studies that were reviewed had economic components. With such data, any economic evaluations can only serve as general guidance for Canadian populations. Cost saving calculations should be based on Alberta data, as these will be much more relevant than data from U.S. sources.

One further issue which needs to be addressed is hospital length of stay data. Again, none of the length of stay data in the literature were produced by studies conducted in Canada. The largely, U.S. data were used to provide a rough estimate of lengths of stay for Canadian patients with various conditions.

Region 4 utilization and cost analysis

For each condition, the number of patients presenting in Region 4 was provided. Relevant ICD-9 CM codes for each condition were given to CRHA corporate data staff, who then searched the regional inpatient and emergency visit databases for these codes. These databases contain all of the discharges/visits for the five Region 4 hospitals which were in operation during the specified time period. The five hospitals are: Alberta Children's Hospital, Bow Valley Centre, Foothills Medical Centre, Peter Lougheed Centre, and the Rockyview General Hospital. The most recent data available from the inpatient database were for the fiscal 1996-1997 year, and for the emergency database were for the 9 month period July 1996 - March 1997. All inpatient and emergency numbers presented in this report are for these time frames.

Costing data in Region 4 were only available for the Foothills Medical Centre. For most conditions, the majority of patients presented at FMC. It was assumed that the costs at FMC are representative of costs incurred for like conditions at other centres. As FMC is the regional trauma centre, it can be expected that patients with more serious problems may present there, though this is an assumption.

Estimates of costs are reported, as opposed to hospital charges, which are often cited in the literature. The inpatient database output includes the following data, by patient (with patient identifiers removed):

- admission date
- discharge date
- length of stay
- laboratory costs
- histology costs
- diagnostic imaging costs
- cardiac laboratory costs
- nursing costs
- OR/RR costs
- respiratory therapist costs
- miscellaneous costs
- residual cost
- total overall cost figure

For each category listed here, the costs are divided into direct costs (i.e. actual time, or cost for a specific test) and overhead. A summary at the bottom of each report includes the total cases, average LOS (days), average cost per case, and average cost per day. These costs do not include physician costs, as this information is only available from the Fee-for-Service File at Alberta Health. As such, the costs presented in this report for non-HBO therapies underestimate the total health system costs incurred.

Finally, only a few patients with some conditions presented in Region 4, generalizations are risky and conclusions must be made with caution. It would have been preferable to go back over 5 years and take the median or mean number of cases and costs per year over that period. However, specific cost records for the region only date back to April 1994, and are generally not viewed as adequately accurate until the fiscal year 1995/96.

Cost of HBOT treatment

An indicative value for cost per dive for HBOT treatment has been based on the recent analysis in Hamilton (16), but taking account of Alberta regulations in respect of physicians' fees.

The cost per dive calculated in the Hamilton analysis was $350, which included a component of $142 for physicians' fees. In Alberta the physician fee for HBO is $26.50 per 15 minutes, for the first session only. Taking the average treatment time to be about an hour, the overall session fee would be about $100. From information supplied by the Edmonton unit, on average there are eight dives per patient treated. Cost per dive is assumed to be $220, based on $208 for capital and operating costs (from the Hamilton analysis) plus $13 for physicians' fees ($100 for 8 dives).

Appendix B: Classification of level of evidence

Table 11: Classification of level of evidence

Level of evidence	*Description*	*Strength*
Level I	Large randomized trials with clear cut results (and low risk of error)	Good
Level II	Small randomized trials with uncertain results (and moderate to high risk of error)	Good - Fair
Level III	Non-randomized, contemporaneous controls	Fair
Level IV	Non-randomized, historical controls	Fair
Level V	No controls, case series only	Poor

From Sackett, 1986 (Reference 48)

Appendix C: Conclusions from review articles

1. Tibbles et al.(52)

Table 12: Results from review by Tibbles et al.

Evidence Supports HBOT	*Evidence Suggests HBOT*	*HBOT not Supported*
arterial gas embolism	selected problem wounds	necrotizing fasciitis
decompression sickness	soft tissue radionecrosis	thermal burns
severe CO poisoning	ORN	
gas gangrene	less severe CO poisoning	
ORN prevention	*ATPIs	
*exceptional blood loss anemia	*Osteomyelitis - refractory	
*skin grafts/flaps - compromised		

*indicates conditions where Tibbles et al. drew conclusions contrary to those of the current review.

2. Doyle & Parfrey (18)

Table 13: Results from review by Doyle & Parfrey

HBOT warranted for	*HBOT likely useful for*
decompression sickness	ORN - mandible
arterial gas embolism	*split skin grafting
CO poisoning	
gas gangrene	

*indicates conditions where Doyle et al. drew conclusions contrary to those of the current review.

Doyle et al. did not find HBOT to likely be useful for soft tissue radiation and problem wounds, whereas the current review did.

3. Grim et al.(27)

Table 14: Results from review by Grim et al.

HBOT warranted for	*HBOT may be useful for*
decompression sickness	*osteomyelitis - refractory
air embolism	tissue radionecrosis
CO poisoning	problem wounds
*ATPIs	
ORN - mandible	
bacterial invasion of a necrotic wound	

*indicates conditions where Grim et al. drew conclusions contrary to those of the current review

4. Sheps (49)

The hyperbaric medicine unit operational costs for Vancouver General Hospital are reported to be $300,000 per year, not including physician fees. The average operating cost per patient comes to about $3450, based on 86 patients treated in 1990-91. The average cost per dive is about $620. Variation in treatment cost exists across different conditions. Further, the costs reported are of the HBO chamber only, and do not include the costs of other components such as surgery and antibiotics. Physician fees (based on '91 BCMA fee schedule) are $65.89 for the first hour and $33.86 for each additional 15 minutes if the physician is in the chamber. If the physician is outside the chamber, the charge is $44.86 for the first 30 minutes and $23.86 for each additional 15 minutes.

For chronic osteomyelitis, the number of sessions ranged from 30-60. This translates into a range of about $6000-14,000 for physician fees alone. The resulting totals could come to $25,000-$30,000 per patient for treatment of this condition with HBO (including physician fees but excluding the costs of other treatment components). This report also reviewed osteoradio-necrosis, but detailed cost calculations were not provided for the use of HBOT for this condition.

Sheps notes a lack of RCTs and argues, unlike many authors, that randomized trials could and should be conducted. He suggests that in the field of HBOT, many more randomized controlled trials are required before it can be concluded that this treatment is medically effective for many conditions for which it has been recommended previously. Further, Sheps states that thorough cost analyses are required as the benefit

of this treatment for many conditions is unclear, and the costs of this treatment are in general high.

The summary presented for refractory osteomyelitis by Sheps indicates that the cost of treating this condition with HBO is extremely high. Thus, even if HBO was shown to be a medically effective treatment for this condition, it is highly unlikely that any cost savings would result. Sheps' cost description for refractory osteomyelitis is valuable for the current situation in Alberta as little information is known about the costs of treating this condition with HBO at present.

References

1) Apelqvist J, Ragnarson-Tennvall G, Larsson J. Topical treatment of diabetic foot ulcers: an economic analysis of treatment alternatives and strategies. *Diabetes Medicine* 1995;12(2):123-128.

2) Bakker DJ. Costridial myonecrosis. In: Davis J, Hunt T, (eds.). *Problem Wounds, The Role of Oxygen.* New York: Elsevier Publishing Company, 1988:pp 153-172.

3) Baroni G, Porro T, Faglia E, et al. Hyperbaric oxygen in diabetic gangrene treatment. *Diabetes Care* 1987;10(1):81-86.

4) Blanshard J, Toma A, Bryson P, Williamson P. Middle ear barotrauma in patients undergoing hyperbaric oxygen therapy. *Clinical Otolaryngology,* 1996;21(5):400-403.

5) Bouachour G, Cronier P, Gouello JP, et al. Hyperbaric oxygen therapy in the management of crush injuries: a randomized double-blind placebo-controlled clinical trial. *Journal of Trauma* 1996;41(2):333-339.

6) Brannen AL, Still J, Haynes M, et al. A randomized prospective trial of hyperbaric oxygen in a referral burn center population. *American Surgeon,* 1997;63(3):205-8.

7) Brown DR, Davis NL, Lepawsky M, et al. A multi-center review of the treatment of major truncal necrotizing infections with and without hyperbaric oxygen therapy. *American Journal of Surgery,* 1994;167:485-9.

8) Bowersox JC, Strauss MB, Hart GB. Clinical experience with hyperbaric oxygen therapy in the salvage of ischemic skin flaps and grafts. *Journal of Hyperbaric Medicine,* 1986;1(3):141-149.

9) Calhoun JH, Cobos JA, Mader JT. Does hyperbaric oxygen have a place in the treatment of osteomyelitis. *Orthopedic Clinics of North America,* 1991;22(3):467-471.

10) Canadian Coordinating Office for Health Technology Assessment. *Selected health technologies in Canada.* Ottawa: CCOHTA, 1996.

11) Cianci P, Hunt TK. Adjunctive hyperbaric oxygen therapy in treatment of diabetic foot wounds. In Levin ME, O'Neill LW, Bowker, JH (eds.), *The Diabetic Foot.* 5th edition. St. Louis, Mosby, 1993 pp 306-319.

12) Cianci P, Hunt TK. Long-term results of aggressive management of diabetic foot ulcers suggest significant cost effectiveness. *Wound Repair and Regeneration,* 1997;5(2):141-146.

13) Cianci P, Sato R. Adjunctive hyperbaric oxygen therapy in the treatment of thermal burns: a review. *Burns,* 1994;20(1):5-14.

14) Cianci P, Williams C, Lueders H, et al. Adjunctive hyperbaric oxygen in the treatment of thermal burns: an economic analysis. *Journal of Burn Care Rehabilitation,* 1990;11(2):140-143.

15) Davis JC, Heckman JD, DeLee JC, Buckwold FJ. Chronic nonhematogenous osteomyelitis treated with adjunct hyperbaric oxygen. *Journal of Bone and Joint Surgery* 1986;68: 1210 -1217.

16) Dempsey J, Hynes N, Smith T, Sproat J. Cost effectiveness analysis of hyperbaric therapy in osteoradionecrosis. *Canadian Journal of Plastic Surgery,* 1997;5(4):221-229.

17) Doctor N, Pandya S, Supe A. Hyperbaric oxygen therapy in diabetic foot. *Journal of Postgraduate Medicine,* 1992;38(3):112-114.

18) Doyle M, Parfrey PS. *Implications of increased use of hyperbaric oxygen therapy in Newfoundland and Labrador.* St. John's: The General Hospital Corporation, 1995.

19) Ducasse JL, Celsis P, Marc-Vergnes JP. Non-comatose patients with acute carbon monoxide poisoning: hyperbaric or normobaric oxygenation? *Undersea and Hyperbaric Medicine,* 1995; 22(1):9-15.

20) Dutka AJ. A review of the pathophysiology and potential application of experimental therapies for cerebral ischemia to the treatment. *Undersea Biomedical Research,* 1985;12(4):403-421.

21) Eltorai I, Hart GB, Strauss MB, et al. The role of hyperbaric oxygen in the management of fournier's gangrene. *International Surgery,* 1986;71:53-58.

22) Esterhai JL, Pisarello J, Brighton CL, et al. Adjunctive hyperbaric oxygen therapy in the treatment of chronic refractory osteomyelitis. *Journal of Trauma,* 1987;27:763-8.

23) Faglia E, et al. Adjunctive systemic hyperbaric oxygen therapy in treatment of severe prevalently ischemic diabetic foot ulcer. *Diabetes Care,* 1996;19(12):1338-43.

24) Feldmeier JJ, Heimbach RD, Davolt DA, et al. Does hyperbaric oxygen have a cancer-causing or -promoting effect? A review of pertinent literature. *Undersea and Hyperbaric Medicine,* 1994;21(4):467-75.

25) Gorman DF, Clayton D, Gilligan JE, Webb RK. A longitudinal study of 100 consecutive admissions for carbon monoxide poisoning to the Royal Adelaide Hospital. *Anaesthesia and Intensive Care,* 1992;20(3):311-316.

26) Gozal D, Ziser A, Shupak A, et al. Necrotizing fasciitis. *Archives of Surgery,* 1986;121:233-5.

27) Grim PS, Gottlieb LJ, Boddie A, Batson E. Hyperbaric oxygen therapy. *Journal of the American Medical Association,* 1990;263:2216-29.

28) Hammarlund C, Sundberg T. Hyperbaric oxygen reduced size of chronic leg ulcers: a randomized double-blind study. *Plastic Reconstructive Surgery,* 1994;93:829-33.

29) Hart GB. HBO and Exceptional Blood Loss Anemia. In: Kindwall E, (ed.). *Hyperbaric Medicine Practice.* Arizona: Best Publishing Co., 1994:pp 519-523.

30) Hart GB, O'Reilly RR, Broussard ND, et al. Treatment of burns with hyperbaric oxygen. *Surgery, Gynecology, and Obstetrics,* 1974;139:693-696.

31) Hart GB, Strauss MB. Gas gangrene -- clostridial myonecrosis: a review. *Journal of Hyperbaric Medicine,* 1990;5(2):125-144.

32) Hirn M. Hyperbaric oxygen in the treatment of gas gangrene and perineal necrotizing fasciitis. *European Journal of Surgery,* 1993;570:1-36.

33) Hollabaugh RS Jr, Dmochowski RR, Hickerson WL, Cox CE. Fournier's gangrene: therapeutic impact of hyperbaric oxygen. *Plastic and Reconstructive Surgery* 1998;101(1):94-100.

34) Kindwall EP. Contraindications and side effects to hyperbaric oxygen treatment. In: Kindwall E, ed. *Hyperbaric Medicine Practice.* Arizona: Best Publishing Co., 1994:pp 47-55.

35) Kindwall EP. Uses of hyperbaric oxygen therapy in the 1990s. *Cleveland Clinical Journal of Medicine,* 1992;59:517-528.

36) Kindwall EP, Gottlieb LJ, Larson DL. Hyperbaric oxygen therapy in plastic surgery: a review article. *Plastic Reconstructive Surgery,* 1991;88(5):989-908.

37) Kol S, Ammar R, Weisz G, et al. Hyperbaric oxygenation for arterial air embolism during cardiopulmonary bypass. *Annals of Thoracic Surgery,* 1993;55:401-403.

38) Marx RE. A new concept in the treatment of ORN. *Journal of Oral Maxillofacial Surgery,* 1983;41:351-357.

39) Marx RE, Johnson RP, Kline SN. Prevention of osteoradionecrosis: a randomized prospective clinical trial of hyperbaric oxygen versus penicillin. *Journal American Dental Association,* 1985;111:49-54.

40) McKenzie MR, Wong FL, Epstein JB, Lepawsky M. Hyperbaric oxygen and postradiation osteonecrosis of the mandible. *European Journal of Cancer,* 1993;29B(3):201-7.

41) Melamed Y, Shuypak A, Bitterman H. Medical problems associated with underwater diving. *New England Journal of Medicine,* 1992;326(1):30-35.

42) Niu AKC, Yang C, Lee HC, et al. Burns treated with adjunctive hyperbaric oxygen therapy: a comparative study in humans. *Journal of Hyperbaric Medicine,* 1987;2(2):75-85.

43) Pelaia P, Rocco M, Volturo P, et al. Arterial air embolism during cardiopulmonary bypass: twelve years experience. *Journal of Hyperbaric Medicine,* 1992;7(2):115-121.

44) Perrins DJD. Influence of hyperbaric oxygen on the survival of split skin grafts. *Lancet,* Apr 22, 1967:868-71.

45) Persels JE. Economic aspects of hyperbaric oxygen therapy. In: Kindwall E, (ed.). *Hyperbaric Medicine Practice.* Arizona: Best Publishing Co., 1994:pp 97-118.

46) Raphael JC, Elkharrat D, Jars-Guincestre MC, et al. Trial of normobaric and hyperbaric oxygen for acute carbon monoxide intoxication. *Lancet,* 1989;2:414-9.

47) Riseman JA, Zamboni WA, et al. Hyperbaric oxygen therapy for necrotizing fasciitis reduces mortality and the need for debridements. *Surgery,* 1990;108:847-850.

48) Sackett DL. How are we to determine whether dietary interventions do more good than harm to hypertensive patients? *Canadian Journal of Physiology and Pharmacology* 1986;64:781-783.

49) Sheps SB. *Hyperbaric oxygen for osteomyelitis and osteoradionecrosis.* Vancouver: British Columbia Office of Health Technology Assessment, October, 1992.

50) Strauss MB. Crush injury and other acute traumatic peripheral ischemias. In: Kindwall E, (ed.). *Hyperbaric Medicine Practice.* Arizona: Best Publishing Co., 1994:pp 526-546.

51) Thom SR, Taber RL, Mendiguren I, et al. Delayed neuropsychologic sequelae after carbon monoxide poisoning: prevention by treatment with hyperbaric oxygen. *Annals of Emergency Medicine,* 1995;25(4):474-80.

52) Tibbles PM, Edelsberg JS. Hyperbaric-oxygen therapy. *New England Journal of Medicine,* 1996;334:1642-1648.

53) Weaver LK, Hopkins RO, Larson-Lohr V, et al. Double-blind, controlled, prospective, randomized clinical trial (RCT) in patients with acute carbon monoxide (CO) poisoning: outcome of patients treated with normobaric oxygen or hyperbaric oxygen - an interim report. *Undersea and Hyperbaric Medicine,* 1995;22:Suppl:14:abstract.

54) Weiss L, Van Meter K. The applications of hyperbaric oxygen therapy in emergency medicine. *American Journal of Emergency Medicine,* 1992;10(6):558-568.

55) Zamboni WA, Risemen JA, Kucan JO. Management of Fournier's gangrene and the role of hyperbaric oxygen. *Journal of Hyperbaric Medicine,* 1990;5(3):177-186.